ePHENIX: Field return design

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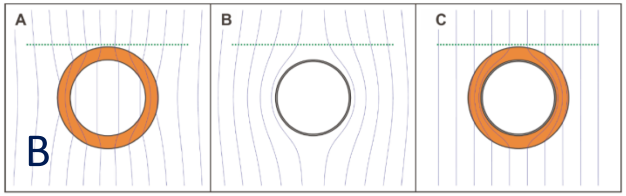
PHENIX

Field return design parameters

- Base on sPHENIX/BaBar magnet and yoke
- Open acceptance for both ePHENIX and fsPHENIX
- Practical limit
  - |z|<4.5m eRHIC detector region limit
  - Height limit of beam-rail of 4.5 m
  - No bending magnetic field on electron beam
- Detector requirements
  - Sufficient momentum resolution in forward region
  - Work with gas RICH: small bending field in RICH region
  - Work with TPC: homogeneous field in TPC region

Field return ideas investigated: We came a long way

Design Family	Example
Piston	• Passive piston (C. L. da Silva) • Super conducting piston (Y. Goto)
Dipole	• Forward dipole (Y. Goto, A. Deshpande, et. al.) • Redirect magnetic flux of solenoid (T. Hemmick) • Use less-magnetic material for a azimuthal portion of central H-Cal (E. Kistenev)
Toroid	• Air core toroid (E. Kistenev) • Six fold toroid (J. Huang)
Other axial symmetric Field shaper	• Large field solenoidal extension (C. L. da Silva) • Pancake field pusher (T. Hemmick)



Beam line magnetic field shielding, based on superconducting pipe.
Test device planned (Stony Brook Group)

Concept for an EIC Detector

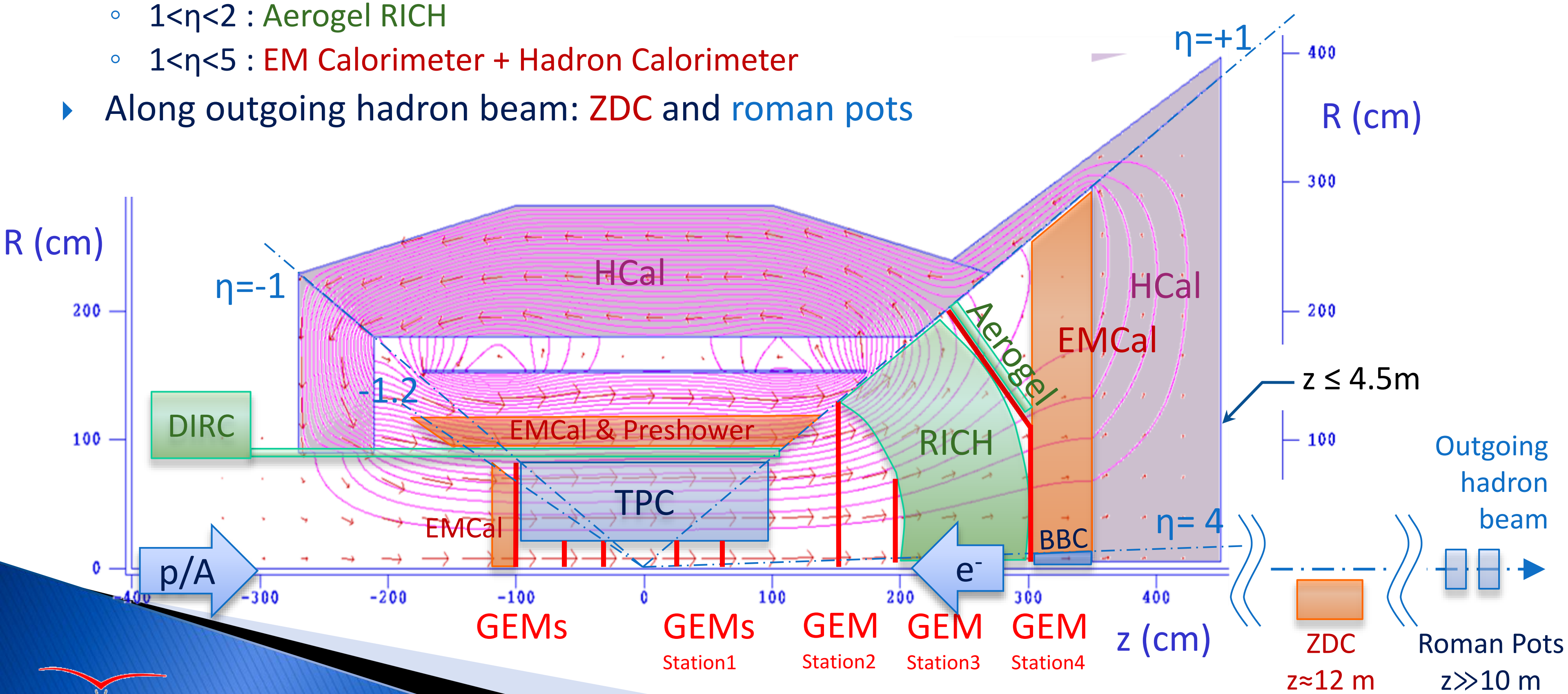
- -1<η<+1 (barrel) : sPHENIX + Compact-TPC + DIRC
- -4<η<-1 (e-going) :
  High resolution calorimeter + GEM trackers
- +1<η<+4 (h-going) :
  - 1<η<4 : GEM tracker + Gas RICH
  - 1<η<2 : Aerogel RICH
  - 1<η<5 : EM Calorimeter + Hadron Calorimeter
- Along outgoing hadron beam: ZDC and roman pots

Working title: "ePHENIX"

LOI: arXiv:1402.1209

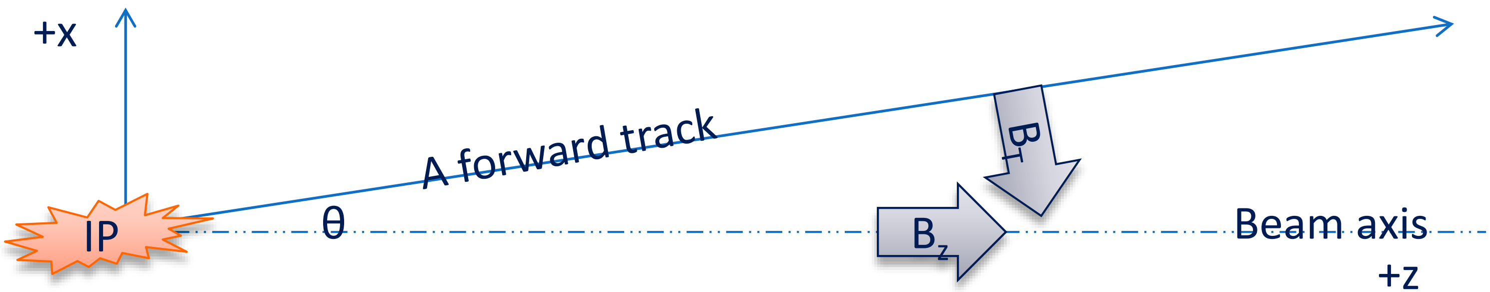
Review: "good day-one detector"

"solid foundation for future upgrades"



Tracking overview for forward directions

- Field transverse to the track → bending of the track → sagitta → measurement of (1/p)
- Besides brutal force increase of tracking resolution/field strength, geometry and field direction play an important role
- For a cylindrical symmetric field:



Transverse field is directly related to shape of central longitudinal field:

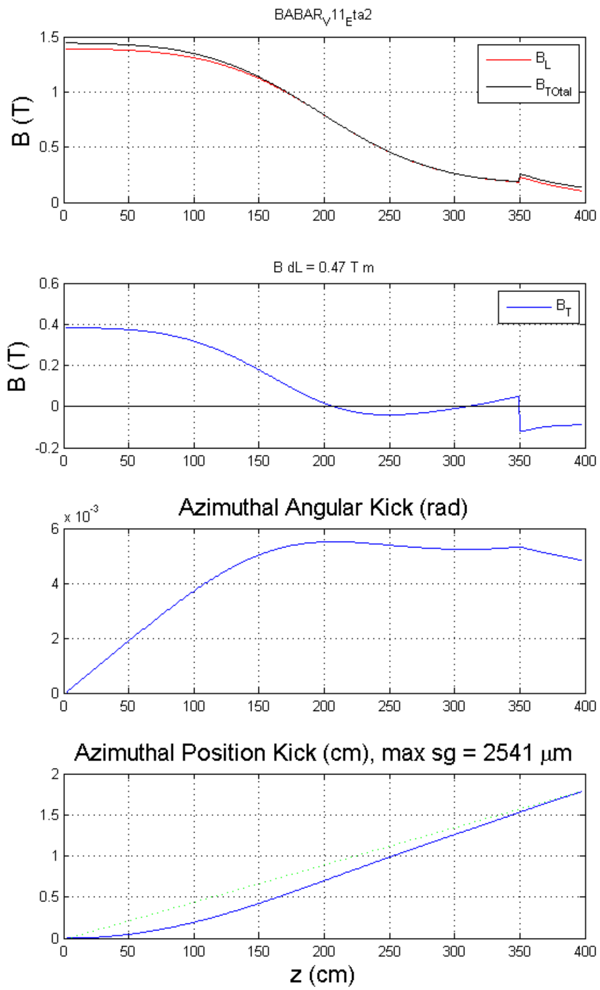
$$\boxed{B_T = B_z \tan\theta + \frac{\tan\theta}{2} z \frac{\partial B_z}{\partial z} + O\left(\theta^2\right)}$$

Geometry Term

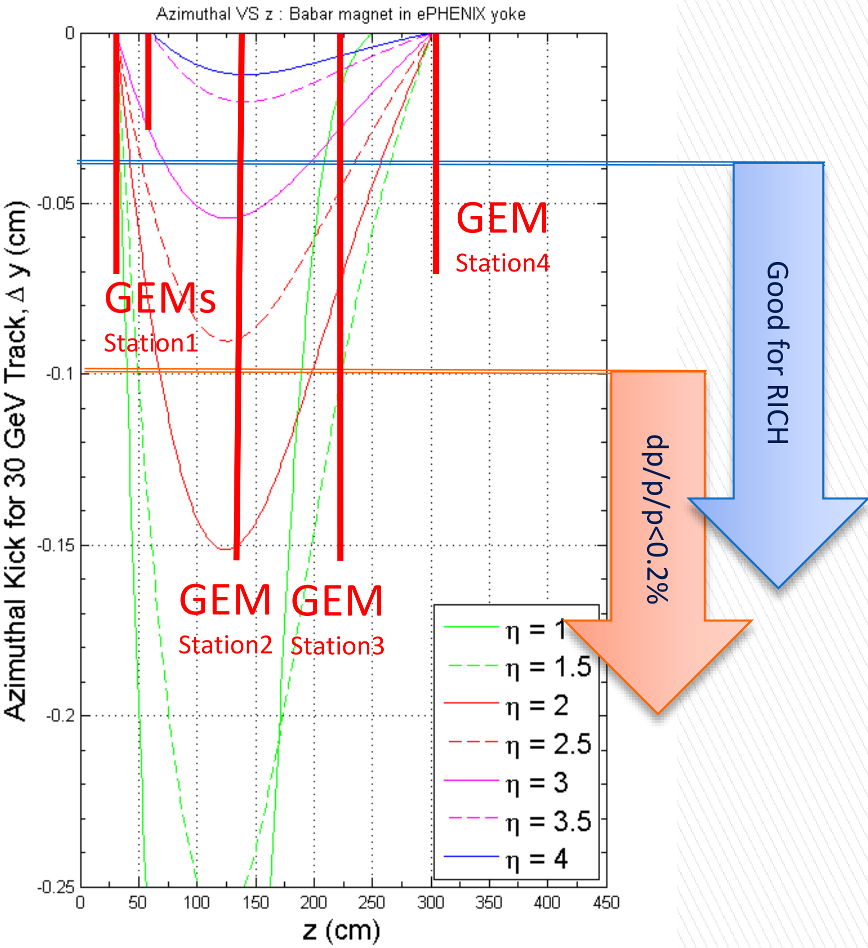
Flux Term

BaBar's graded current density help both

Tracking optimization with numerical field simulation



Using ϕ segmented GEM
with resolution of R Δϕ = 50µm



Magnetic bending
Track of η=2.0, p=30 GeV

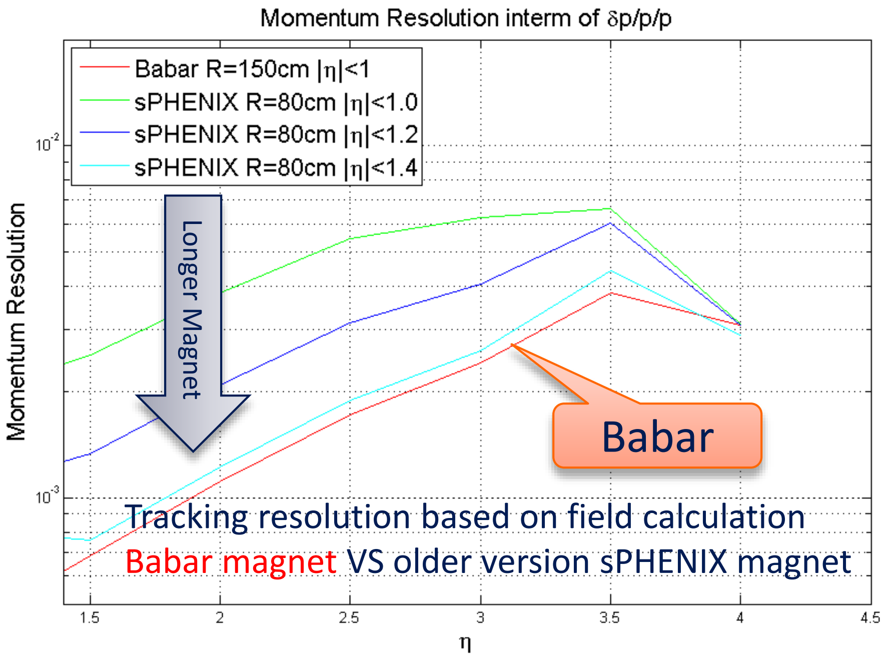
Summary for sagitta
Track of p=30 GeV

PH

BaBar + Field shaping

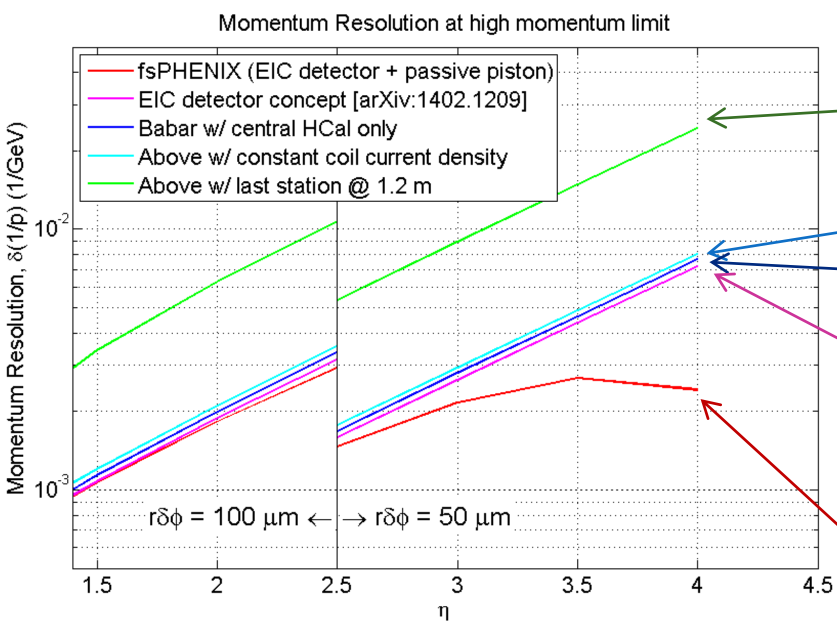
- BaBar superconducting magnet became available
  - Built by Ansaldo → SLAC ~1999
  - Nominal field: 1.5T
  - Radius : 140-173 cm
  - Length: 385 cm
- Field calculation and yoke tuning
  - Three field calculator cross checked: POISSION, FEM and OPERA
- Favor for forward spectrometer
  - Designed for homogeneous B-field in central tracking
  - Longer field volume for forward tracking
  - Higher current density at end of the magnet -> better forward bending
  - Work well with RICH with field-shaping yoke: Forward & central Hcal + Steel lampshade
- To be shipped soon

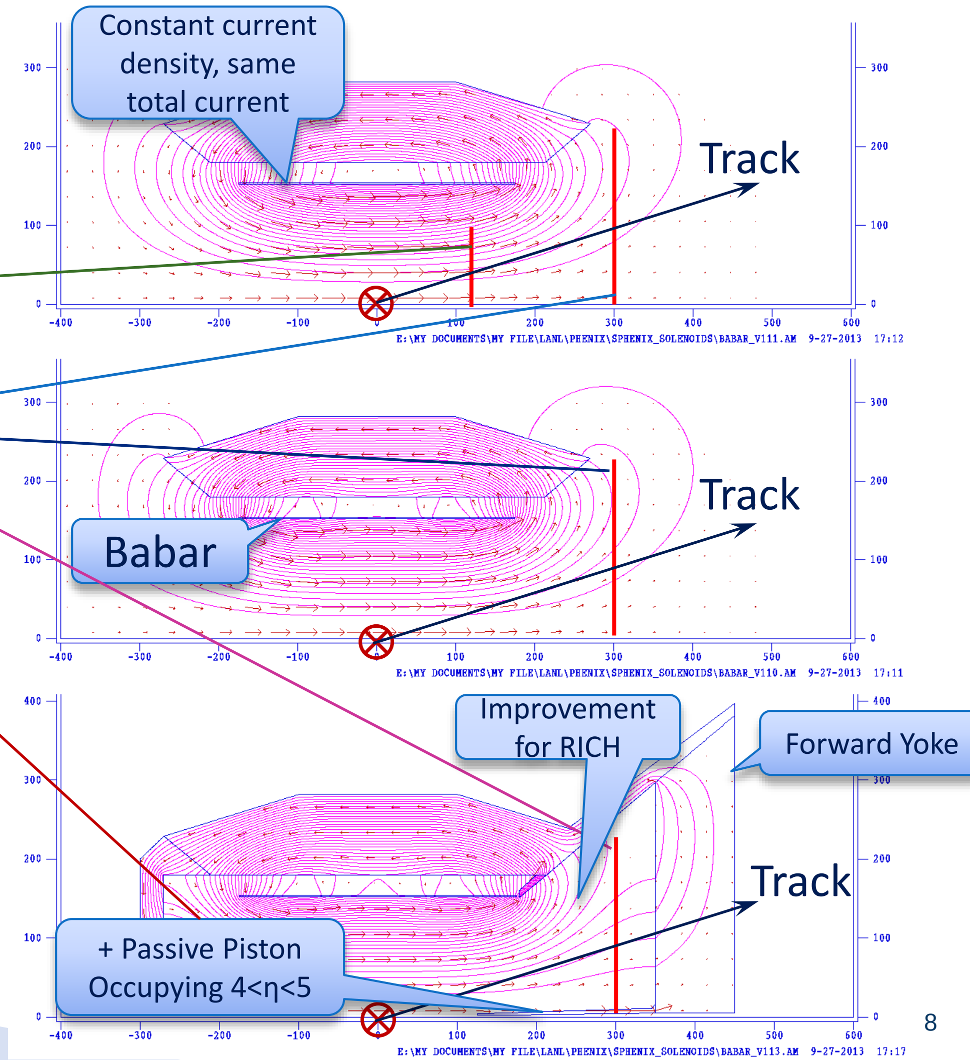

BaBar solenoid packed for shipping, May 17 2013



Considerations for yoke and tracking designs

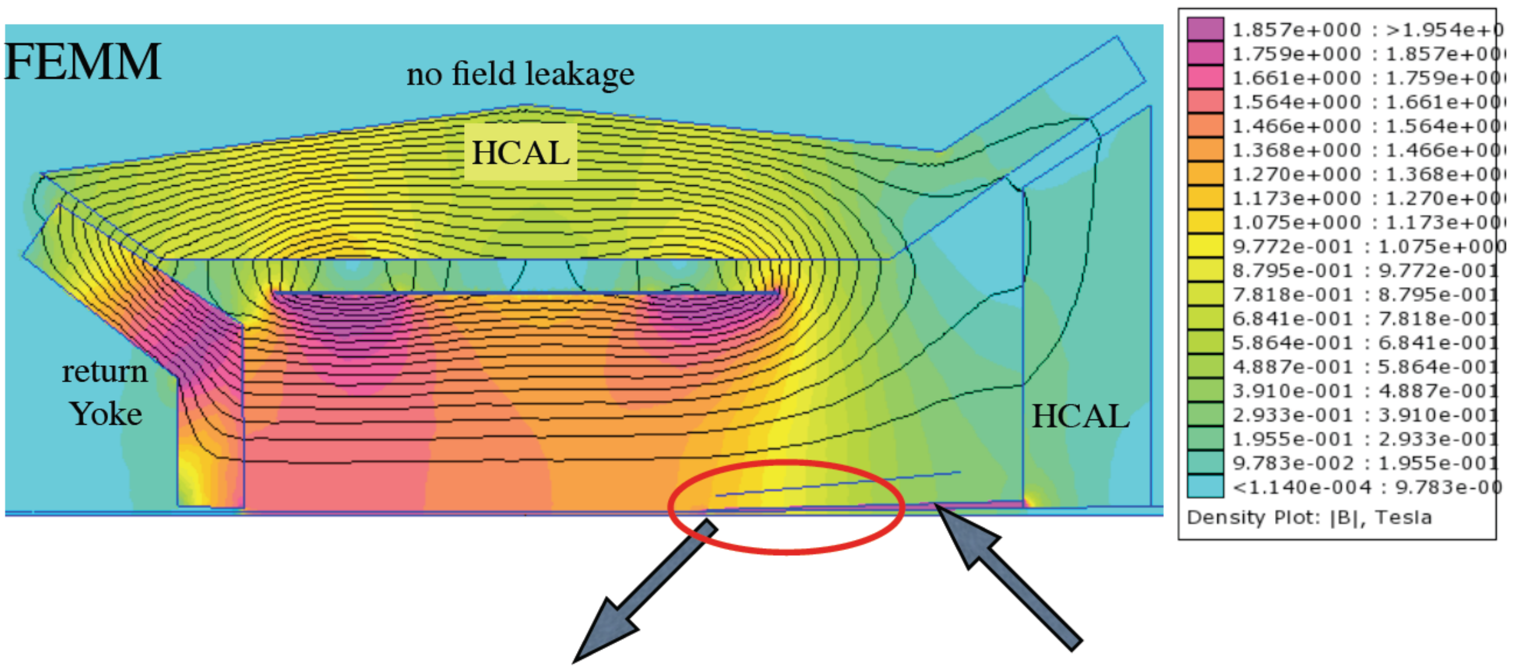
- Optimal tracking configurations
  - Measure sagitta with vertex – optimal sagitta plane (not drawn) – last tracking station
  - Yoke after tracking space and conform with a |z|<4.5m limit (eRHIC machine/detector t”ruce” line)
- Baseline forward tracking
  - Central + forward yoke (hadron calo.)
  - Last tracking station at z=3.0m
- Can be further enhanced for fsPHENIX DY

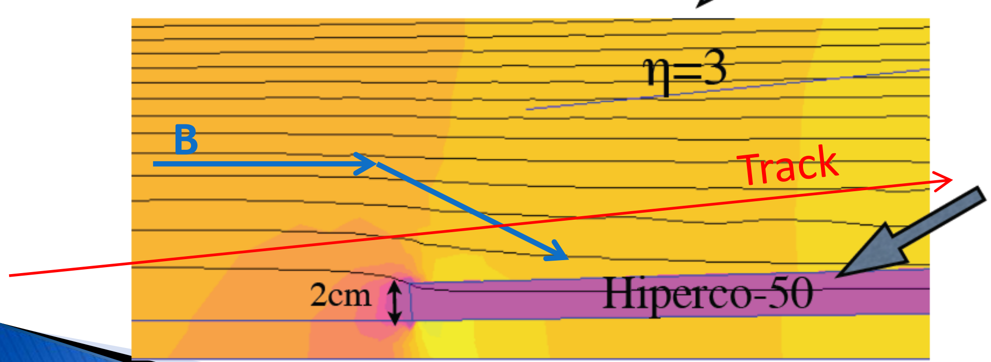




Very forward tracking for fsPHENIX: Passive piston field shaper

by C. L. da Silva





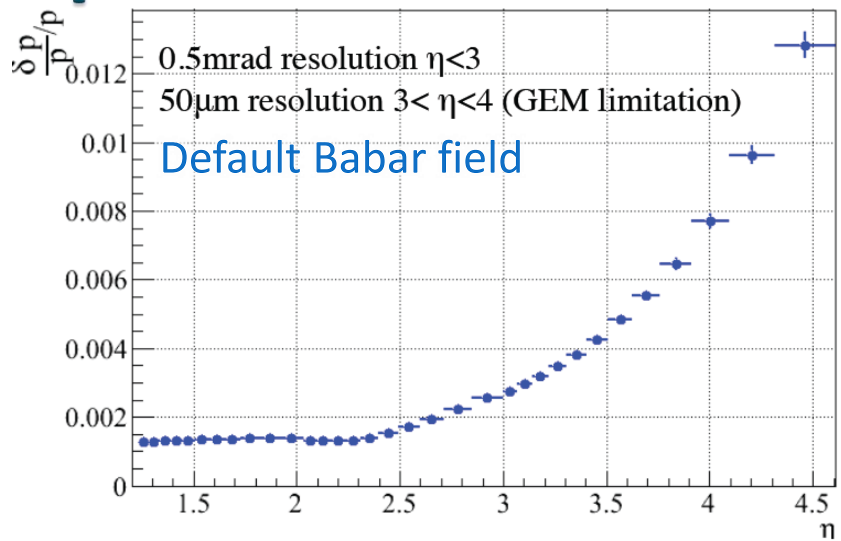
Passive Piston helping flux return at small angle

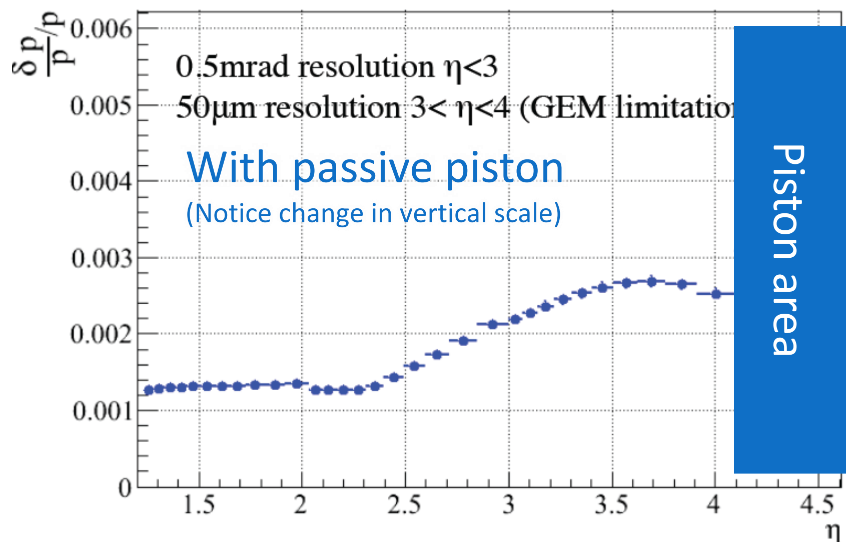
Hiperco-50: 49%Co+49%Fe alloy provide high field saturation (<2.25T)

Very forward tracking for fsPHENIX : Passive piston field shaper Performance

by C. L. da Silva

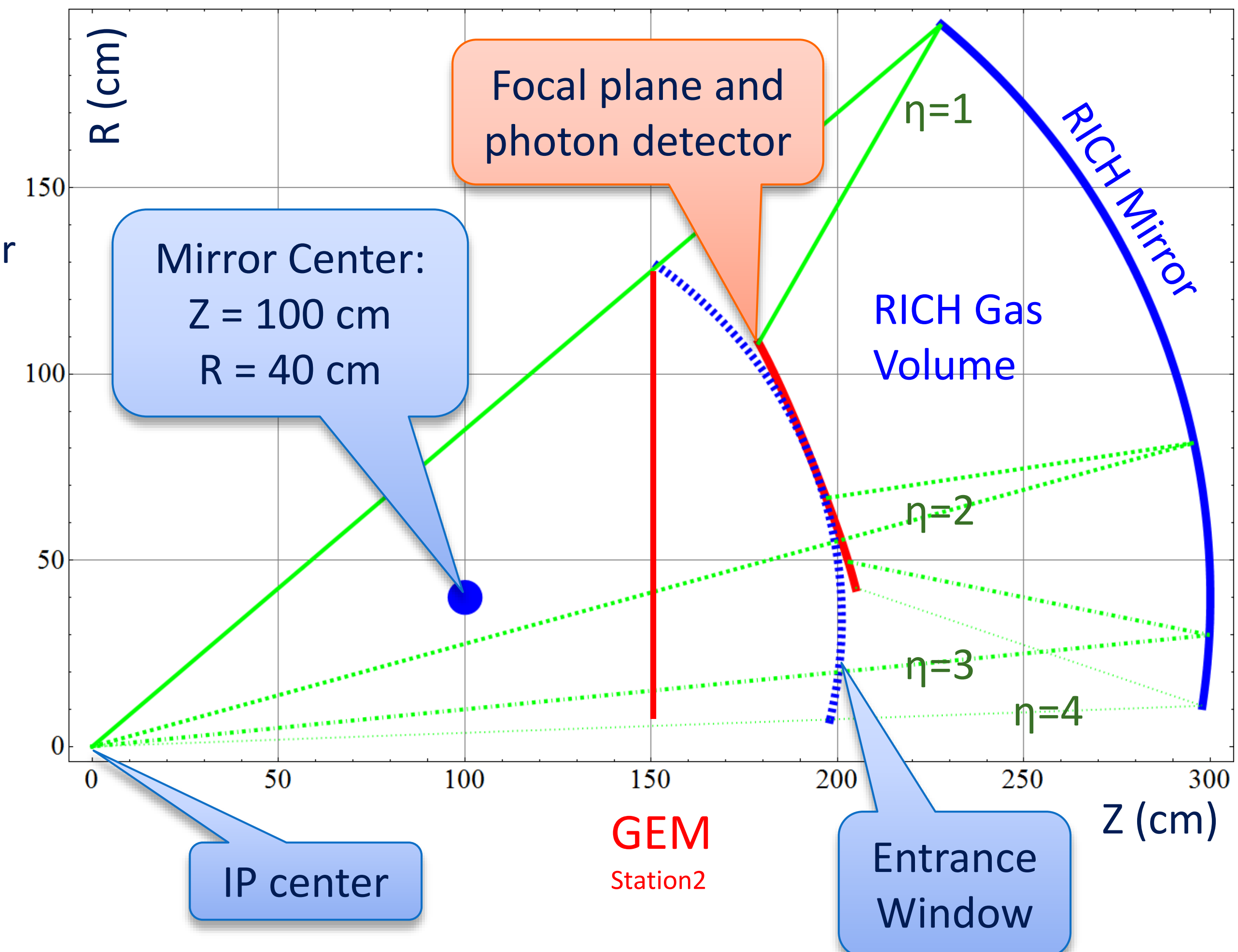
- Advantage :
  - Significantly improved very forward field where Babar field is least effective
  - Simple implementation
  - Minimal interaction with Babar field and beam
- Challenges that under study
  - Blocking Hcal acceptance of 4<η<5 for diffractive studies
  - Background shower from piston
  - Further improvement limited by total piston flux (may use silicon detector)
- Good ideas for improving momentum resolution is there. Not have to use for stage-I EIC, Not in LOI base design.





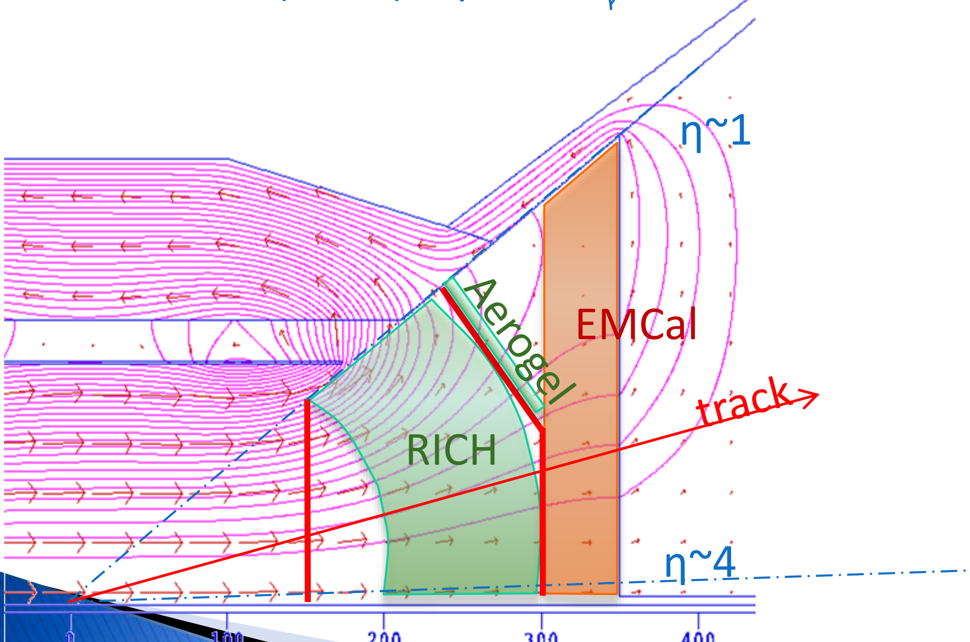
RICH with ePHENIX tracking and field: Proposed Design: R-Z projection

- “Beautiful” optics and assuming spherical mirrors
- 1 meter RICH gas volume along track
- Photon sensor is flat (easier for GEM construction)
- Small area for photon readout
- Avoid invading tracking space (Z > 1.5m, away from the optimal sagitta plane)
- Z < 3.0m from EMCal limit and allow a volume for aerogel at lower eta
- Defocusing due to extended vertex is small for most (Z-η). Defocusing <5% θMAX for worse case(Z-η) = (50 cm, 1.0)



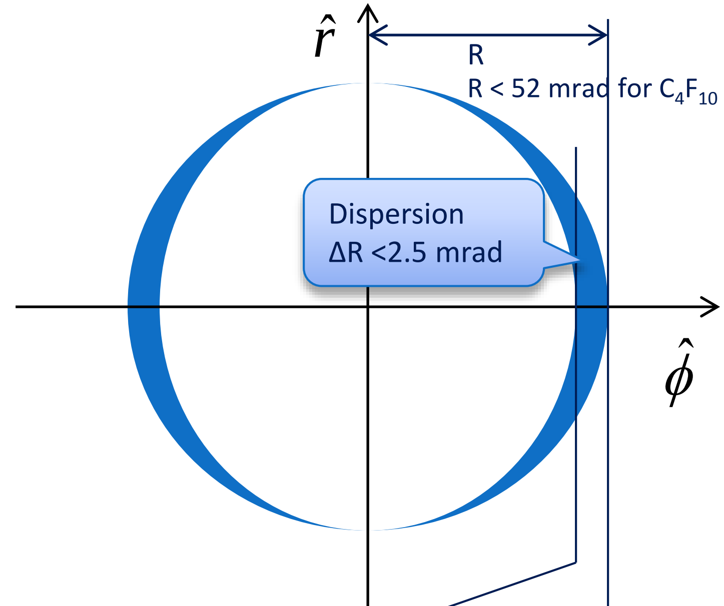
Estimating field distortion for RICH

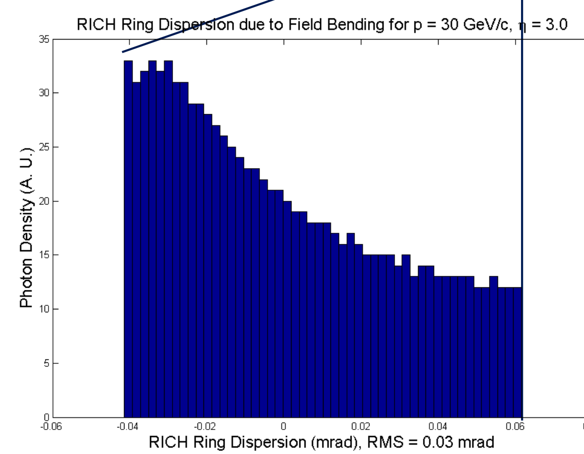
- Field calculated numerically with field return
- Field lines mostly parallel to tracks in the RICH volume
- Field distortion of RICH ring only contribute to a minor uncertainty
  - Uncertainty on R suppressed by $1/\sqrt{(2 \text{ dim})}$ $1/p$, $1/\sqrt{N_\gamma}$



A RICH Ring:

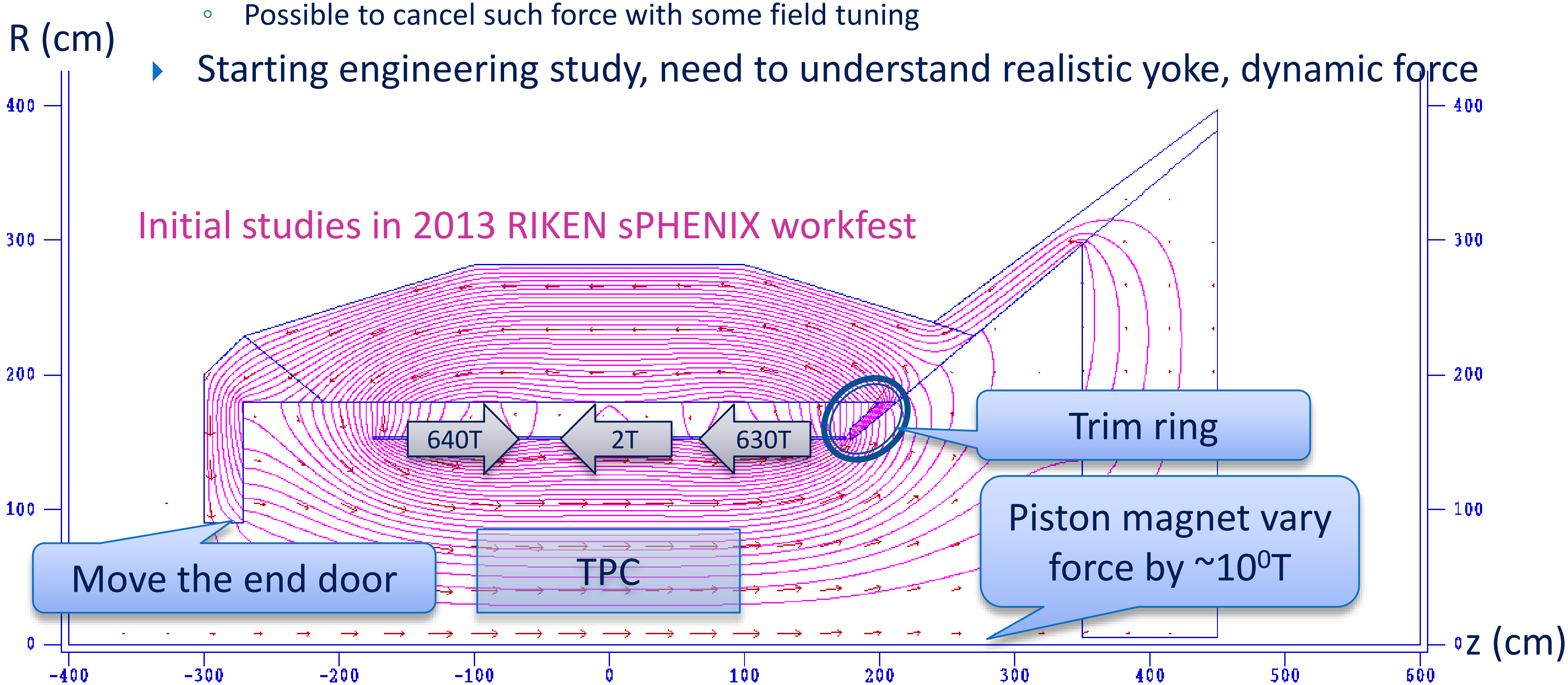
Photon distribution due to tracking bending only





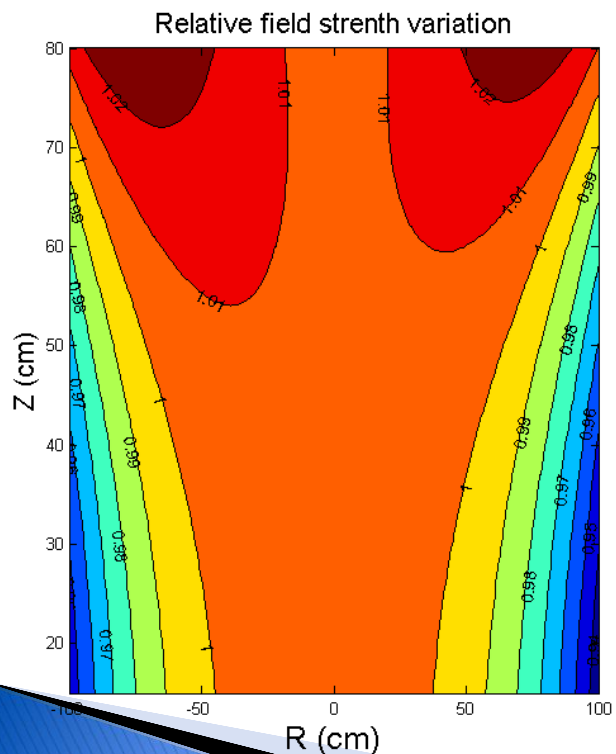
Forward yoke and force

- Forward yoke modification is the foundation for fsPHENIX and ePHENIX, which require joint design at early stage of sPHENIX construction
- Preliminary force calculation done in 2D models to evaluate force and field uniformity
  - Default static force ~ 300T longitudinally
  - Possible to cancel such force with some field tuning
- Starting engineering study, need to understand realistic yoke, dynamic force

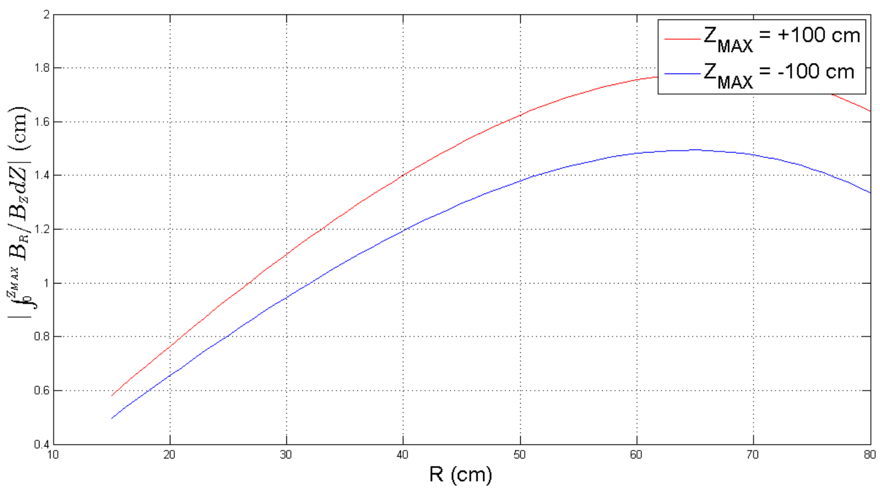


TPC region

- Reached quoted uniformity for Babar (±3% for central tracking volume)
- Looks promising for TPC work condition. Detailed study needed.



Field correction ~ few mm in Rϕ



Summary

- Current design satisfies the requirement in leading order
  - Base on sPHENIX/BaBar magnet and yoke
  - Open acceptance for both ePHENIX and fsPHENIX
  - Practical limit
    - |z|<4.5m eRHIC detector region limit
    - Height limit of beam-rail of 4.5 m
    - No bending magnetic field on electron beam
  - Detector requirements
    - Sufficient momentum resolution in forward region
    - Work with gas RICH: small bending field in RICH region
    - Work with TPC: homogeneous field in TPC region
- Need more work on
  - Justify the mechanical and dynamic stability
  - Simulation in details with detectors
  - Build it